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Earth Science

Understanding Our Changing Planet

The goal of NASA's Earth Science Enterprise is to better understand the total Earth system and the effects of natural and human-induced changes on the global environment. NASA is pioneering the emerging interdisciplinary field of research called Earth System Science, born of the recognition that Earth's land surface, oceans, atmosphere, ice sheets, and life are both dynamic and highly interactive. Earth System Science can produce immense benefits to the Nation, yielding new knowledge and tools for improved weather forecasting, agriculture, urban and land-use planning, and many other related areas of both economic and environmental importance. In concert with other agencies, the global research community, and commercial partners, NASA is providing the scientific foundation needed for complex policy choices that lie ahead on the road to sustainable development.

Program

From El Niño and shifting weather patterns to ozone depletion and rising levels of greenhouse gases in the atmosphere, much has been learned in the past 10 years about how Earth's environment changes. But there is much more to be learned about the mechanisms that drive these changes, and in distinguishing between natural and human-induced forces. The ultimate product of the Earth Science Enterprise is credible information and common scientific understanding that will provide an objective basis for policymakers to formulate sound decisions about the environment, while enabling the public and private sectors to make productive use of the underlying data. To that end, NASA is developing a series of spacecraft to study the planet and a vast data base to catalog the findings. The Earth Observing System (EOS) and its Data and Information System (EOSDIS) will enable a variety of users, from research scientists to students in the classroom to state and local officials and the business community, to obtain and use NASA-generated science data.

Current Activities

The Earth Science Enterprise uses NASA's unique capabilities from the vantage points of space, aircraft, and in-situ platforms to conduct a wide range of activities. In space, this includes the Terra Great Observatory, a spacecraft that is providing spectacular new insight into our planets global environment, the Tropical Rainfall Measuring Mission, the Sea-viewing Wide Field-of-View Sensor (SeaWiFS) ocean color mission, the QuikScat and TOPEX/Poseidon ocean studies missions, and the ACRIMSAT and Upper Atmosphere Research Satellite (UARS) missions. Instruments aboard aircraft are measuring atmospheric chemistry, biomass burning, and land-surface changes ranging from Greenland to the tropical Pacific Ocean.

Earth Science Enterprise Recent Accomplishments

Research

1999 was a year of substantial scientific accomplishment in our understanding of the major elements that comprise the Earth system. Over the oceans, NASA reduced the uncertainty in global rainfall over the tropics by one half, helping improve short-term weather prediction and availability of freshwater globally. The Office of Earth Sciences produced near-daily ocean color maps that help us understand the role of oceans in removing carbon dioxide from the atmosphere. NASA documented the waxing and waning of El Nino, enabling seasonal climate prediction, and resumed global measurement of winds at the ocean surface to improve short-term weather prediction and tracking of major hurricanes and tropical storms globally.

Over the ice caps, NASA researchers determined the thinning and thickening rates for the Greenland ice sheet, provided the first detailed radar mosaic of Antarctica, and provided the daily observations of the polar regions from space. Over the

land, the Earth Sciences Enterprise produced the first satellite-derived assessments of global forest cover. NASA began refreshing the global archive of 30m land cover data, and conducted an international field experiment in Amazonia to help understand the role of vegetation on Earth in removing carbon dioxide from the atmosphere.

In the solid Earth, NASA and USGS measured surface displacement, a precursor to earthquakes, in the Los Angeles basin. In the atmosphere, NASA continued to measure concentrations of both ozone and ozone-depleting substances and assess the recovery of upper ozone correlation and implemented a 17-year data record of aerosols and cloud properties toward predicting annual to decadal climate variations.

The Office of Earth Sciences continues to fulfill its commitment to make its Earth observation data widely available for researchers and educators. Almost 1,300,000 distinct users obtained 5.2 million data products during the year. Earth Sciences sponsored 350 workshops to train over 11,000 teachers in the use of Earth science concepts and teaching tools, and awarded 50 new fellowships to maintain support for 150 graduate students at U.S. universities annually so as to train the next generation of Earth scientists.

Applications

NASA is making sure its data and associated information and knowledge lead to practical solutions for businesses and local governments. The Office of Earth Sciences established 29 partnerships of various types to develop applications of Earth remote sensing data in the areas of agriculture, natural resources management, urban and regional planning, and disaster mitigation. Over 100 partnerships with a variety of commercial firms help them to use remote sensing data to develop or improve their products and services. NASA researchers contributed to four national and international scientific assessments of the environment that will provide policy-makers with an objective basis for decisionmaking.

Past Accomplishments

Beginning with the 1959 launch of Vanguard II, which returned the first photograph from space of Earth's cloud cover, NASA has been studying the global perspective of our environment. Other NASA accomplishments in observing Earth include:

- **1960:** NASA launched the Television Infrared Observation Satellite (TIROS) I, which proved that satellites can observe Earth's weather patterns. Subsequent TIROS satellites improved hurricane-tracking techniques and severe storm warnings, protecting lives and property in coastal areas around the world.
- **1966:** Environmental Sciences Services Administration I and II gave the United States its first global weather satellite system.
- **1972:** NASA began the Landsat series. Landsats 4 and 5 continue to observe Earth's land surfaces.
- **1975:** The satellites SMS-A, the first spacecraft to observe Earth from geosynchronous orbit, and SMS-B started producing cloud-cover pictures every 30 minutes for weather forecasters.
- **1976:** Laser Geodynamic Satellite I provided scientists with the ability to track very precisely the movements of Earth's surface, increasing our understanding of earthquakes and other geological activity.
- **1978:** The Heat Capacity Mapping Mission demonstrated the ability to measure variations in Earth's temperature from space, paving the way for future climate studies.
- **1978:** Seasat demonstrated techniques for global monitoring of Earth's oceans.
- **1978:** Nimbus 7, the final satellite in the series, was launched carrying a TOMS instrument that provided 14 years of data on Earth's ozone layer. Data from TOMS were part of the scientific basis for the Montreal Protocol and other treaties banning the manufacture and use of ozone-depleting chemicals. The satellite's Coastal Zone Color Scanner obtained a data set that would be widely used to study the links between the oceans' biology and Earth's climate.
- **1984:** The Earth Radiation Budget Satellite began its study of how Earth absorbs and reflects the Sun's energy.
- **1991:** NASA's second TOMS was launched aboard a Russian Meteor-3 satellite.
- **1991:** UARS began its study of the chemistry and physics of Earth's atmosphere. UARS data are used to create global maps of ozone-destroying chemicals and to understand the processes related to ozone depletion better. By 1994, the comprehensive data set from UARS had provided conclusive evidence that human-made chemicals are a major source of the stratospheric chlorine compounds responsible for the annual Antarctic ozone hole.
- **1992:** Data from the U.S.-French TOPEX/Poseidon satellite began to detail the links between Earth's oceans and climate. By 1994, TOPEX data indicated that Earth's average global sea level had risen in the two previous years.
- **1992–1994:** ATLAS, a Space Shuttle payload, flew three times to study the chemistry of Earth's upper atmosphere

and the Sun's radiative output, and the effect of those two elements on ozone levels.

- **1994:** The Space Radar Laboratory flown aboard two Space Shuttle flights demonstrated the uses of a complex radar to study Earth's surface, with applications in ecology, geology, water-cycle studies, and other areas. Related research released in 1996 shed new light on the Great Wall of China and the geological history of the Nile River.

- **1996:** The Earth Science Enterprise published its first Science Research Plan, a strategy for study in five major Earth System Science areas: land-cover and land-use change, seasonal-to-interannual climate variability and prediction, natural hazards research and applications, long-term climate natural variability and change research, and atmospheric ozone research.

- **1997:** NASA conducted the first Biennial Review of the Earth Science Enterprise. This review, which examined all aspects of the program, established a framework for selecting future missions based on the latest science findings, validated the basic plan for the EOS Chemistry spacecraft, and recommended a phased approach to the deployment of the EOS ground data system.

- **1998:** NASA used the Tropical Rainfall Measuring Mission satellite to create extraordinary new models of hurricanes off the coast of Florida. These models have helped researchers understand how the most powerful storms on Earth are formed and transport their deadly energy within our atmosphere.

- **1999:** The Earth Sciences Enterprise began launching its newest fleet of Earth Observing spacecraft. Terra, the first Earth Observing Great Observatory was launched from California and is conducting spectacular new Earth Science. QuikScat, a mission to monitor ocean winds, and ACRIMSAT, a mission to observe solar radiation, also were successfully sent into orbit by NASA.

Partnerships

The Earth Science Enterprise links NASA to a variety of partners. In the United States, it is part of the U.S. Global Change Research Program, which coordinates the environmental research of 11 cabinet departments and agencies. Major interagency cooperation includes work with the U.S. Geological Survey on the Landsat 7 program and with NOAA and the Defense Department on the next generation of polar-orbiting weather satellites. NASA funds research at universities across the country and cooperates with many commercial partners, including a recent scientific data purchase. Internationally, NASA's Earth Science partners span the globe, such as long-time space collaborators like Japan, Germany and Canada.

Applications

Though focused primarily on basic research, data from NASA Earth Science missions have already produced numerous applications to everyday life:

- NASA-sponsored researchers produce regular "greenness maps" that track the growth and health of crops in the Midwest.

- Data from Landsat 7 is used to develop techniques to track the loss of coastal marshes along the Chesapeake Bay, which may have implications for the area's fishing and tourist industries.

- The first TOMS instrument, which provided 14 years of continuous data on global ozone levels, provided part of the scientific pinning for treaties banning the use of ozone-depleting chemicals. TOMS data also are used by the Federal Aviation Administration to re-route aircraft around areas of jet engine-damaging airborne volcanic ash.

- TOPEX/Poseidon data are used to monitor El Niño, a periodic change in climate patterns that can bring devastating rains to California and drought to Australia. These data helped predict the 1997 El Niño six months in advance.

- The Lightning Imaging Sensor is producing high-quality images of lightning on a global scale, showing that 90 percent of lightning occurs on land surfaces.

- The Space Shuttle Radar Topography Mission orbited the Earth aboard Shuttle Endeavour, collecting the most comprehensive maps of Earth in only 11 days. These 3-D datasets will revolutionize our understanding of Earth's surface.